# Hydrogen Purification Technologies Overview

## 2021 ARPA-E Methane Pyrolysis Annual Program Review Virtual Meeting

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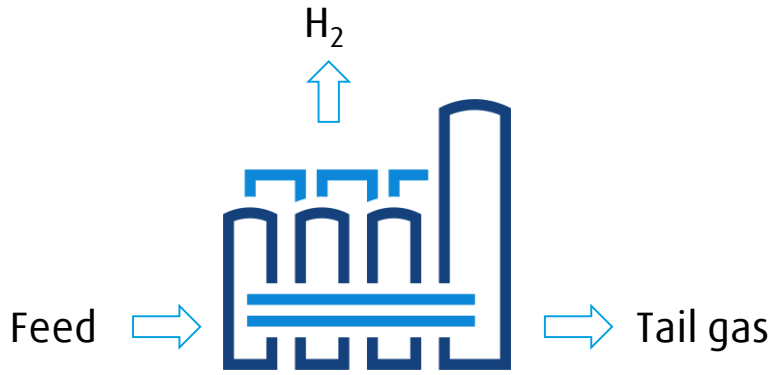
# Overview of $H_2$ Purification Technologies

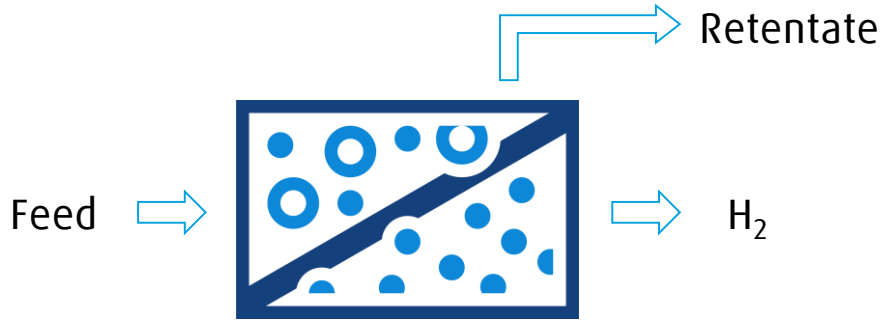
## PSA (Pressure swing adsorption)

- Most common method used in $H_2$ plants
- Suitable for small to very large capacities
- Requires feed at pressure
- Produces $H_2$ at pressure and impurities are removed at near-ambient pressure in tail gas
- $H_2$ purity of up to 99.9999 vol.% achievable

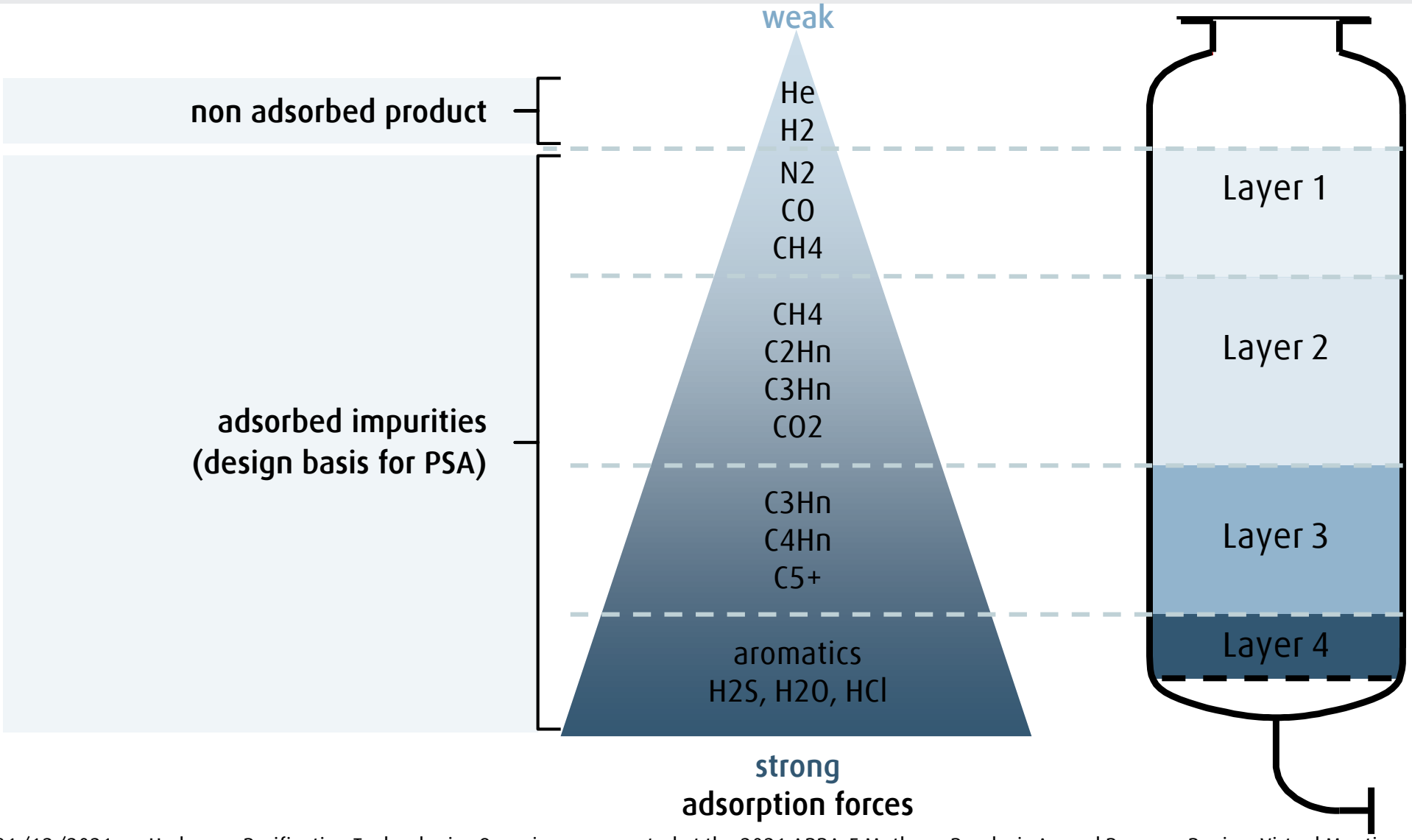



## Membranes

- Used in niche $H_2$ separation applications (e. g. syngas ratio adjustment, recovery from $H_2$-rich off gases)
- Economical at lower capacities
- Requires feed at pressure
- Produces $H_2$ at low pressure and impurities are removed at about feed pressure in the retentate
- Product $H_2$ compressor may be required
- $H_2$ purity is 95 – 98% vol. from a single stage



# PSA technology: Layered Bed for $H_2$ Purification



# PSA Equipment – Supplied as Package Unit

## Adsorber Vessel and Tail Gas Drum

## Prefabricated Valve Skid

## Process Control System


## Adsorbent Material

# Applications for PSA Hydrogen Recovery

## Feed Gas

## PSA

## Pure Hydrogen Product

### Feed Gas Sources

**Synthesis Gases:**
- Steam Reformer
- Partial Oxidation
- Gasification
- $CH_4$ pyrolysis

**Refinery Off-Gases:**
- Catalytic Reformer
- CCR
- Aromatic Plants
- other H2-rich streams

**Petrochemical Off-Gases:**
- Ethylene Plants
- Methanol Plants
- Ammonia Plants

**Coke Oven Gas**

| Typical Ranges | |
|---|---|
| Pressure | 5 – 70 bar(a) |
| H2 content | 30 – 99 vol. % |
| Temperature | 10 – 40 °C |
| Flow | Up to 500,000 Nm3/h |

### Tailgas (Impurities + $H_2$)

**Utilized as Fuel Gas:**
- to fuel gas network
- to reformer furnace

| Typical Range | |
|---|---|
| Pressure | 1.1 – 7 bar(a) |

### Hydrogen Consumers

| Typical Range | |
|---|---|
| $H_2$ purity | 99 – 99.9999 vol. % |

**Refinery:**
- Hydrocracker
- Hydrodesulfurization

**Ammonia Synthesis**

**MeOH Synthesis**

**Petrochemical Processes:**
- Olefin & Polyolefin
- Aromatics
- Hydrogen Peroxide

**Others:**
- Iron & Steel Industry
- Float Glass Production
- Food Industry
- Electronic Industry
- $H_2$ Fuel / Fuel Cells

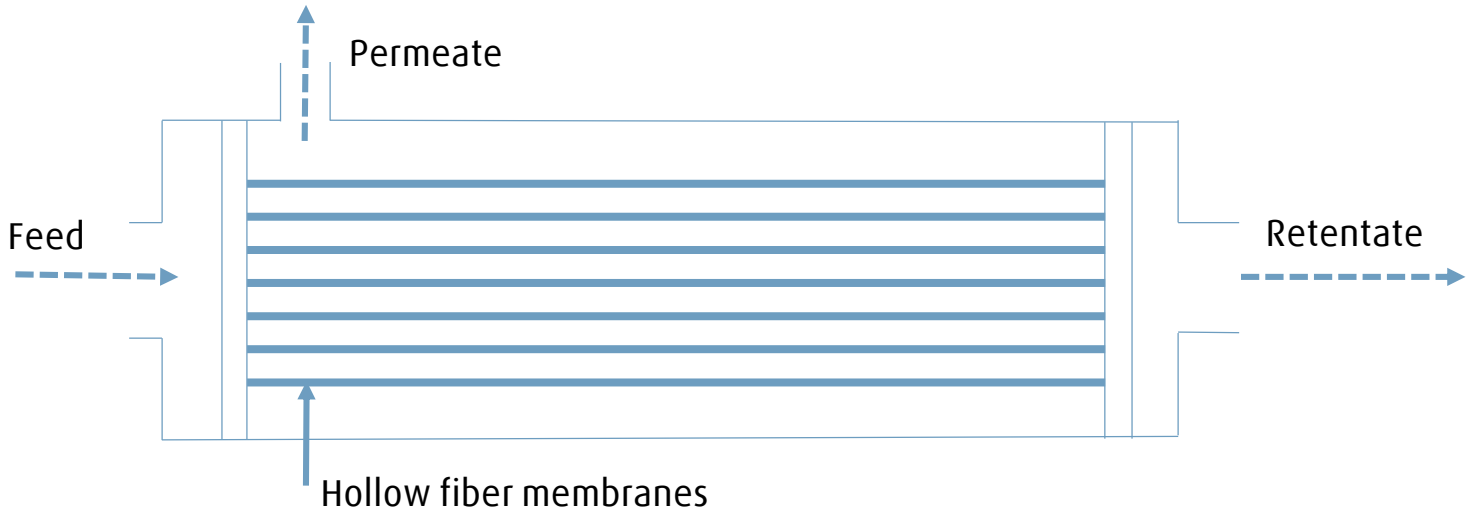
# Polymeric Membranes in Gas Separation

- **Glassy Polymers**
- Gases dissolve into surface
- Diffusion controlled transport
- More soluble components permeate quicker (small molecule → high flux)
- $H_2$, He, $CO_2$ removal/recovery processes

## Typical Permeation Properties

slow — Glassy-Polymer — fast

$C_6H_{14}$ $C_3H_8$ $C_2H_6$ $CH_4$ $N_2$ CO $CO_2$ $H_2$ He $H_2O$



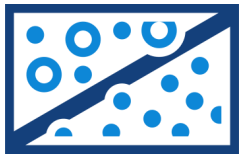
# Membrane Applications for Hydrogen Separation

- Syngas $H_2$:CO ratio adjustment by removing some hydrogen
- Hydrogen extraction from NG-$H_2$ mixture
- Hydrogen recovery from refinery off-gas streams
- Hydrogen recovery from purge streams in different processes
- $H_2$ rejection from olefin streams

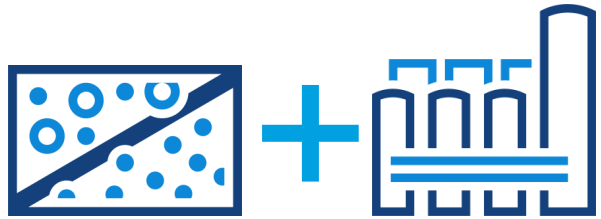
# Considerations for $H_2$ Purification in Methane Pyrolysis Plants

- Pre-cleanup including separation of solids and liquids from raw $H_2$ stream
- Feed compression to desired pressure for separation
- Full characterization to define all the components including trace impurities
- Integration of purification technology with $CH_4$ pyrolysis
- $H_2$ purification technology selection and optimization will depend on
  - Production capacity
  - Feed pressure and composition
  - Product purity and recovery targets
  - Product and tail gas or retentate pressures
  - Integration with rest of the process (use of tail gas or retentate)

PSA



Membranes



Membrane-PSA Hybrid

**Final Solution Could be PSA, Membranes (Single or Multi-Stage) or Membrane-PSA Hybrid**

# Thank you for your attention.

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